

THREE PAIRED-TOW STUDIES TESTING FOR EQUIVALENCE IN SHRIMP SAMPLING

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ABSTRACT Three sets of shrimp catch data from paired tows between the FRS OREGON II and other research vessels were analyzed. Two-way analysis of variance and Wilcoxon's signed-ranks tests were used. Recommendations for minimizing effort and maximizing information gain are given.

INTRODUCTION

Sampling a large population such as that of brown shrimp along the Texas Gulf coast requires an extensive effort. Estimation of the standing stock of this brown shrimp population would entail a large sampling effort--too large for a single vessel to accomplish in the short time period available. Thus the need arises to use two or more vessels and standardize their catch rates.

The National Marine Fisheries Service (NMFS) studied the shrimp stock in the northwest Gulf of Mexico during the 1981 and 1982 Texas Closures (May to July), using several vessels. During the 1981 study, the FRS OREGON II of NMFS was assisted in its sampling program by the RV WESTERN GULF of the Texas Parks and Wildlife Department (TPWD). In 1982, a similar study was incorporated into the SEAMAP program and the FRS OREGON II was assisted in its sampling of a much wider area by three vessels: the RV TOMMY MUNRO of the Gulf Coast Research Laboratory (Mississippi); the RV JEFF & TINA, contracted by NMFS to collect off Louisiana; and the RV FLORA MAE, contracted by TPWD to collect off Texas. Paired tows were made between the FRS OREGON II and the other vessels, except the RV FLORA MAE, to test for sampling equivalence.

This report reviews the three paired-tow studies involving the FRS OREGON II. It also offers recommendations on methodology for paired-tow operations in general.

THEORY

Paired Tows

Under ideal conditions, several paired tows are made between vessels at the start of a sampling program. The data obtained are analyzed on the spot to identify differences in catch rates and to make necessary changes in a vessel's rigging or techniques. If changes are required, additional paired tows are made to again test for equivalence in sampling. The essential features of such a paired-tow test are worth briefly defining: 1) Usually there are only two vessels involved. 2) Standard sampling gear and rigging are used, the

same as will be used during the remainder of the sampling program. 3) Both vessels tow at their normal trawling speeds; it is preferable that these speeds be identical, but not essential, as the most important point is that each vessel should use its normal trawling speed (i.e., the trawling speed to be used during the remainder of the sampling program). 4) The towing time during a paired tow should be the same as for standard sampling. 5) Vessels should be as close together as feasible during each paired tow, as it is essential that both vessels sample the same population density.

Statistics

Analysis of catch rates from paired tows can be accomplished with either parametric or non-parametric statistical tests. Each method has its limitations and requirements. The appropriate parametric test is the two-way analysis of variance (ANOVA). It requires that sampling be random, that the error components of each measurement be independent and normally distributed, and that the variances be equal. Replicate measurements are needed from each vessel to test the data for these requirements. The Wilcoxon's signed-ranks test is the appropriate non-parametric test for paired tows. Its limitation is that it requires a minimum of six paired tows to detect a significant difference between vessels' catch rates at the 95% probability level. If a significant difference is detected, adjustments are made to the gear, rigging, and techniques used. If differences still exist after retesting with more paired tows, correlation and regression analyses are used to establish a standardization equation equilibrating catch rates between the two vessels.

CASE STUDIES

FRS OREGON II and the RV WESTERN GULF

During the 1981 Texas Closure, nine paired tows were made by the FRS OREGON II and the RV WESTERN GULF. Port and starboard nets were towed from each vessel during each of the paired tows, and each tow lasted 30 minutes. Catch rates ranged from 0.1 to 79.1 lb of shrimp per 30 min drag with a 42-ft semiballoon shrimp trawl (Table 1).

TABLE 1.

Shrimp catch rates and their means and variances for paired tows between the FRS OREGON II and the RV WESTERN GULF during the 1981 Texas Closure. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl.

OREGON II

Port	Starboard	Mean	Variance
8.9	6.0	7.45	4.205
4.7	4.0	4.35	0.245
75.1	40.1	57.60	612.500
41.5	33.4	37.45	32.805
79.1	30.2	54.65	1195.600
35.6	24.4	30.00	62.720
9.5	5.0	7.25	10.125
10.9	8.1	9.50	3.920
8.6	4.9	6.75	6.845

WESTERN GULF

Port	Starboard	Mean	Variance
7.9	6.5	7.20	0.980
6.6	5.4	6.00	0.720
60.5	62.5	61.50	2.000
36.5	35.0	35.75	1.125
57.0	55.5	56.25	1.125
5.3	5.0	5.15	0.045
9.7	11.4	10.55	1.445
7.8	6.3	7.05	1.125
1.1	1.8	1.45	0.245

Within-vessel means and variances of catch rates for each of the paired tows were calculated and used to test the requirements for analysis of variance. Bartlett's test for homogeneity of variances (Sokal and Rohlf 1969) and Taylor's method for assessing the relationship between the variances and the means (Taylor 1961) showed the original catch rates should be transformed before applying an ANOVA.

Taylor's method states: $\text{LOGvariance} = A + B$ (LOGmean), with the suggestion that:

if $B =$ transform the original data to their:
 1 square roots
 2 logarithms
 3 or more negative fractional exponent ($=Z$)
 $Z = 1 - B/2$

For the FRS OREGON II and RV WESTERN GULF paired tows, $B = 1.498$, and I chose to transform the data to their natural logarithms.

The 2-way ANOVA showed significant differences in mean catch rates between vessels and among paired tow locations (Table 2). The interaction term was also significant, indicating that the differences between vessels were dependent upon location. Observing the catch rates and plotting the two-tracks of the vessels for each paired tow (Figure 1), it became evident that during the sixth and ninth paired tows, the FRS OREGON II probably sampled areas with greater shrimp concentrations than did the RV WESTERN GULF. After inspecting the other catch data (= finfish plus miscellaneous) for all paired tows, it became apparent that shrimp patchiness was the problem. When data from the sixth and ninth tows were

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TABLE 2.

Comparison of two two-way ANOVA tests for shrimp catch rates of paired tows by the FRS OREGON II and the RV WESTERN GULF during the 1981 Texas Closure. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl; data were transformed to their natural logarithms.

A. NINE PAIRED TOWS (=LOCATIONS)				
Source of Variation	DF	SS	MS	F
Locations	8	6.7947	0.8493	55.7613***
Vessels	1	0.1451	0.1451	9.5256**
Interaction	8	0.9462	0.1183	7.7648***
Error	18	0.2742	0.0152	
Total	35	8.1602		

B. SEVEN PAIRED TOWS (=LOCATIONS)				
Source of Variation	DF	SS	MS	F
Locations	6	4.9427	0.8238	55.5095***
Vessels	1	0.0112	0.0112	0.7512 ns
Interaction	6	0.0646	0.0108	0.7250 ns
Error	14	0.2078	0.0148	
Total	27	5.2261		

*** = significant at the 99.9% level.
 ** = significant at the 99.0% level.
 ns = not significant at the 95% level.

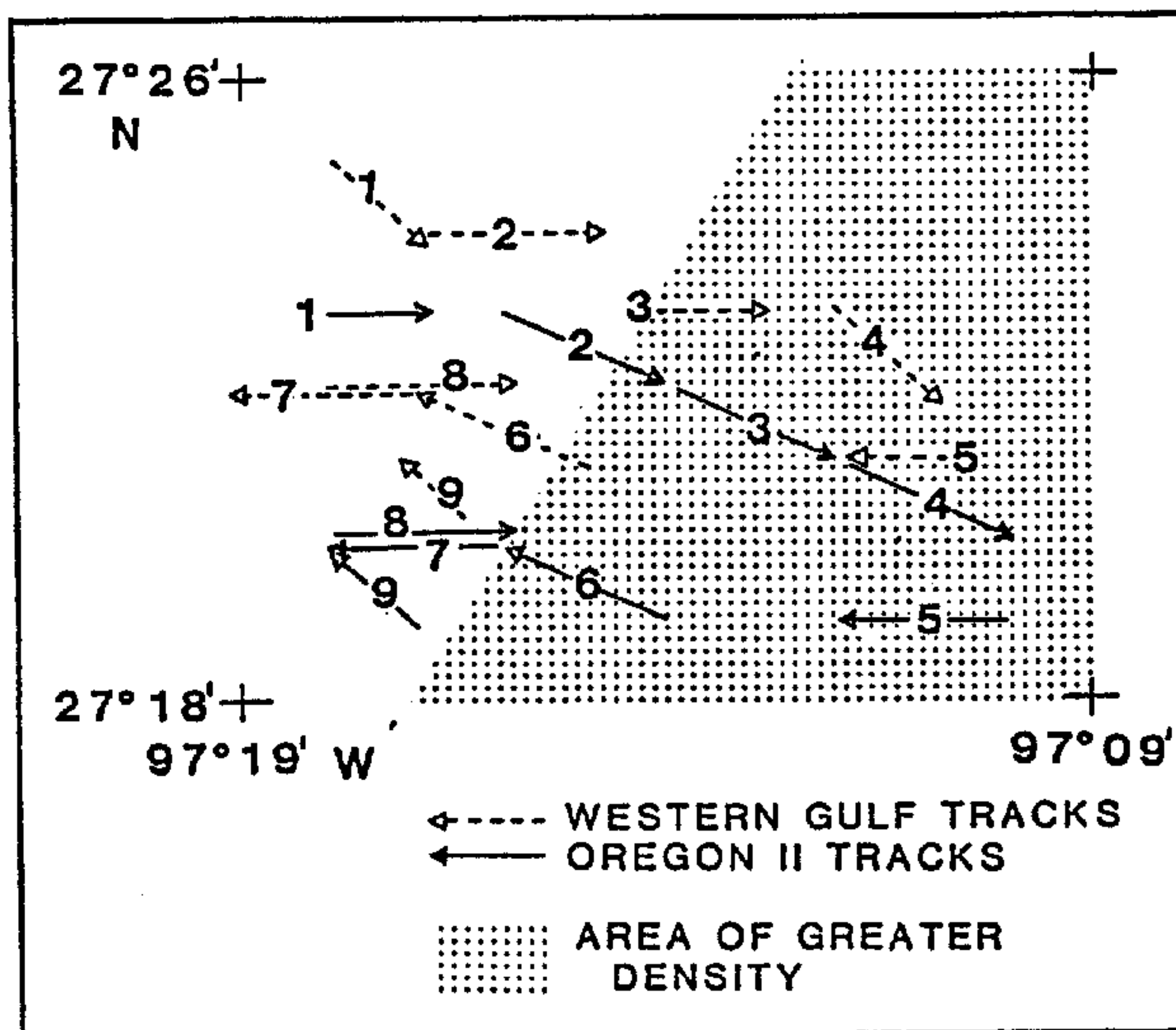


Figure 1. Tow tracks for the paired tows made by the FRS OREGON II and the RV WESTERN GULF during the 1981 Texas Closure survey.

discarded and the ANOVA performed on the remaining seven, only the differences among the mean catch rates for the paired tows (= locations) remained significant. The differences between vessels, and the interaction term were no longer significant, suggesting the two vessels were sampling equivalently and a standardization factor need not be calculated.

FRS OREGON II and the RV TOMMY MUNRO

During the 1982 SEAMAP study, seven paired tows were made between these two vessels. Only one net was towed by each vessel during each paired tow. Trawling times varied under 30 minutes. All catch rates were standardized to the equivalents of 30-min tows to make them comparable. The 30-min shrimp catch rates ranged from 0.55 to 8.86 lb (Table 3). Because there were no replicates but there were more than six tows, a Wilcoxon's signed-ranks test was used to test for differences between the vessels' catch rates.

A significant difference between vessels was detected (Table 3). Inspection of the data revealed large differences between vessels and those differences did not correlate ($r = 0.07$ n.s.). It appears there was a problem in gear, rigging, technique or a combination of these aboard the RV TOMMY MUNRO which prevented it from catching shrimp consistently in proportion to the catches made by the FRS OREGON II. An adjustment in gear, rigging, and technique, followed by additional paired tows and subsequent analysis, would have been proper in this case. As it stands, the data from the RV TOMMY MUNRO cannot be standardized with those of the FRS OREGON II. We should note two things about the catch rates of the RV TOMMY MUNRO: first, they are probable underestimates of shrimp abundance; and second, the differences between the vessels' catch rates were declining steadily, which suggests that improvements in gear adjustments and sampling technique were being made aboard the RV TOMMY MUNRO to obtain more accurate samples.

TABLE 3.

Shrimp catches, catch rates, differences, and signed ranks for paired tows by the FRS OREGON II and the RV TOMMY MUNRO during the 1982 SEAMAP study. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl (= CPUE).

Tow No.	Vessel	Minutes towed	Catch	CPUE	Differences in CPUE	Signed rank
1	OREGON II	22	6.5	8.9		
	TOMMY MUNRO	22	0.4	0.6	8.3	+6
2	OREGON II	30	8.4	8.4		
	TOMMY MUNRO	30	0.7	0.7	7.4	+5
3	OREGON II	10	2.6	7.8		
	TOMMY MUNRO	9	0.9	3.0	4.8	+4
4	OREGON II	30	5.1	5.1		
	TOMMY MUNRO	28	1.8	1.9	3.2	+3
5	OREGON II	17	2.4	4.2		
	TOMMY MUNRO	15	0.6	1.2	3.0	+2
6	OREGON II	11	0.5	1.4		
	TOMMY MUNRO	10	0.3	0.9	0.5	+1
7	OREGON II	12	0.5	1.2		
	TOMMY MUNRO	12	0.5	1.2	0.0	none

Results of a Wilcoxon's signed ranks test:

Sum of the "+" = 21

Sum of the "-" = 0

T = 0*

* = significant at the 95.0% level

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FRS OREGON II and the RV JEFF & TINA

Only four paired tows were made by the FRS OREGON II and the RV JEFF & TINA during the 1982 SEAMAP closure study. Again, only one net was towed by each vessel during each paired tow, and trawling times were usually less than 15 minutes. Catch rates were standardized to the equivalents of 30-min tows, and as such, ranged from 0.0 to 9.9 lb (Table 4). A paired comparison test could be used to test for differences between vessels' catch rates, but inspection of the catch rates revealed a substantial interaction component which would make the F-test in the ANOVA inefficient and misleading. This would typically end the analysis with insufficient statistical support for concluding whether the vessels were equivalent samplers.

A meaningful way to continue the analysis of these data is to obtain a substitute measure of the expected within-vessel error, using it to test for interaction and for differences in catch rates between vessels and among tows (= locations). Such an error term was obtained from five paired tows made by the FRS OREGON II and the RV WESTERN GULF in 1981, where the catch rates were in the range of catch rates for this case (see Table 1). Admittedly, this is making the assumption that the within-vessel error for the FRS OREGON II has not changed, and that the within-vessel error of the RV JEFF & TINA was of a similar magnitude.

The two-way ANOVA on LOG (catch rate +1)-transformed data showed significant differences among paired tows (= locations) and between vessels (Table 5). The interaction term was not significant at the 95% level, but was at the 98%

level. A plot of the tow-tracks showed the possibility that the FRS OREGON II sampled in a dense patch of shrimp during the third paired tow while the RV JEFF & TINA did not (Figure 2). When the third paired tow was discarded, only the differences among the three remaining paired tows were significant. With substantial reservations, it appears these two vessels were equivalent samplers and that no standardization was required.

RECOMMENDATIONS

1) Paired-tow tests should be made at the start of a sampling program, and the data analyzed on the spot in case changes and retesting are required.

2) Vessels should be as close together as feasible when making paired tows. If they are not sampling the same density of shrimp, data from the paired tow might be discarded, resulting in a waste of time and effort. The likelihood of sampling different densities increases with distance between vessels.

3) Towing duration should be the same as for standard sampling operations.

4) A minimum of six paired tows should be required, permitting application of either a parametric test (two-way ANOVA or a paired comparisons test) or a non-parametric test (Wilcoxon's signed-ranks test).

5) Port and starboard nets should be used by each vessel for each tow.

6) Accurate and precise recordings of starting and stopping positions and times should accompany each tow in case tow-tracks and density plots are needed to clarify differences or to justify discarding certain deviant tows.

LITERATURE CITED

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TABLE 4.

Shrimp catches and catch rates for paired tows by the FRS OREGON II and the RV JEFF & TINA made during the 1982 SEAMAP survey. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl (= CPUE).

Tow No.	Vessel	Minutes towed	Catch	CPUE
1	OREGON II	12	0.3	0.8
	JEFF & TINA	12	0.0	0.0
2	OREGON II	14	3.9	8.4
	JEFF & TINA	13	4.3	9.9
3	OREGON II	17	3.4	6.0
	JEFF & TINA	15	0.5	1.0
4	OREGON II	10	0.5	1.5
	JEFF & TINA	11	0.4	1.1

TABLE 5.

Comparison of two two-way ANOVA tests for shrimp catch rates of paired tows by the FRS OREGON II and the RV JEFF & TINA during the 1982 SEAMAP study. Catch rates (+1) were transformed to their natural logarithms. The error term was computed from 1981 data using paired tows between the FRS OREGON II and the RV WESTERN GULF.

A. FOUR PAIRED TOWS

Source of variation	DF	SS	MS	F
Locations	3	4.4808	1.4936	28.075**
Vessels	1	0.4226	0.4226	7.944*
Interaction	3	0.5448	0.1816	3.414 ns
Error	9	0.4788	0.0532	

B. THREE PAIRED TOWS

Source of Variation	DF	SS	MS	F
Locations	2	4.4332	2.2166	41.665**
Vessels	1	0.0572	0.0572	1.075 ns
Interaction	2	0.1255	0.0628	1.180 ns
Error	9	0.4788	0.0532	

** = significant at the 99.0% level.
 * = significant at the 95.0% level.
 ns = not significant at the 95.0% level.

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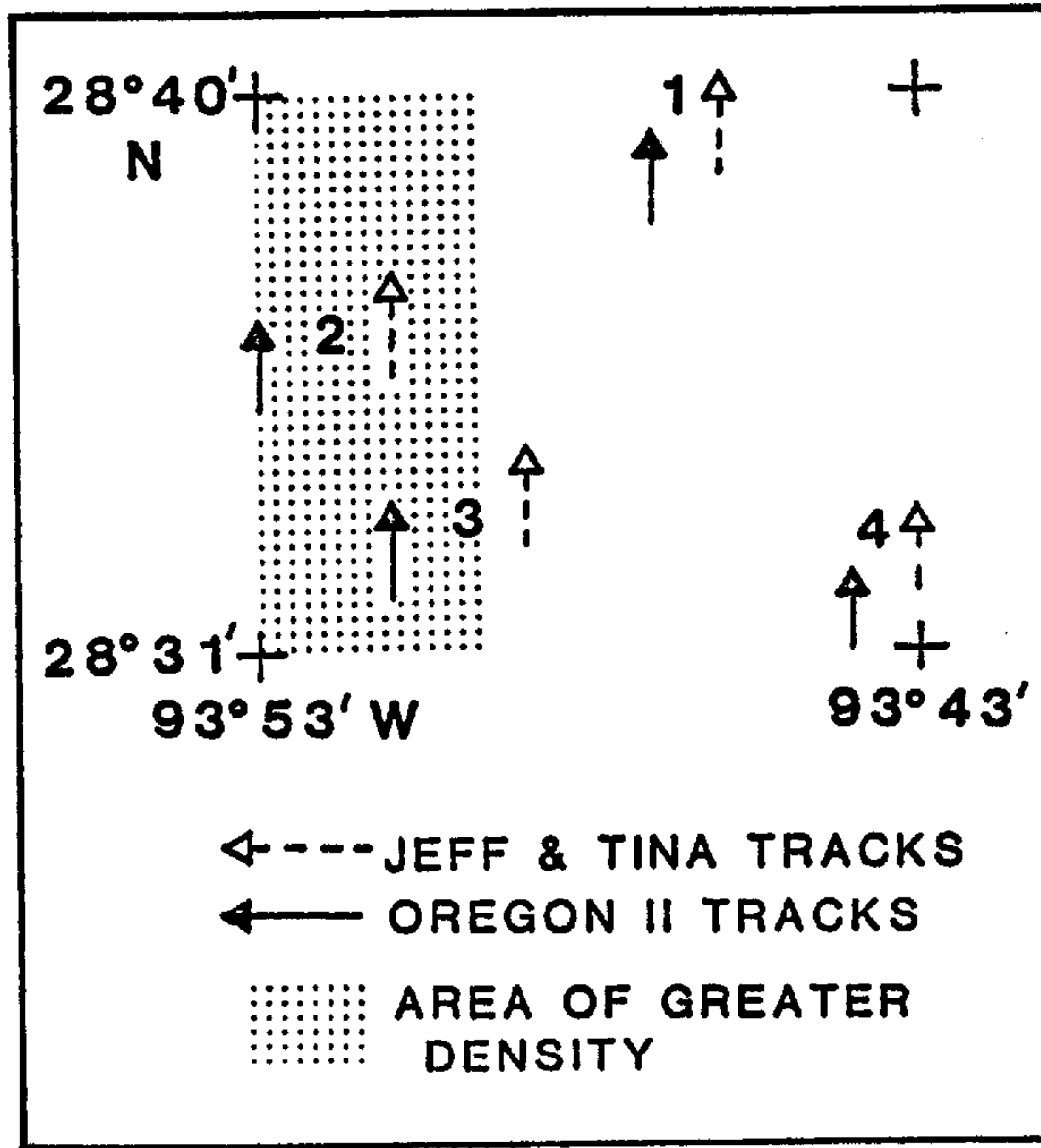


Figure 2. Tow tracks for the paired tows made by the FRS OREGON II and the RV JEFF & TINA during the 1982 SEAMAP survey.